
5. CENTER FOR BUILDING TECHNOLOGY IN THE 80s

5.1 Overview

As Fiscal Year 1981 began on October 1, 1980, the Center for Building Technology (CBT), had a staff of 199 work years, and was preparing, at the request of the Secretary of Commerce, a proposal for a new Construction Productivity Program at a level of \$100 million annually. However, management of the National Bureau of Standards (NBS) was concerned about the high proportion (about 40 percent) of CBT's funding from the Department of Energy, and requesting that the energy work be focused on measurement.

As Fiscal Year 1990 ended on September 30, 1990, CBT had a staff of 89 work years, and was about to become part of the new Building and Fire Research Laboratory (BFRL) of the National Institute of Standards and Technology (NIST) as NBS had been renamed in 1987.

The prospects for major growth of building research at NBS ended with the results of the Presidential election of 1980. Reductions of about 30 percent in CBT staff occurred in 1981 to respond to both reductions in other

agency funding and Administration requirements for reductions in NBS staffing. The President's budget proposal for fiscal year 1984, which was announced in January 1983, called for elimination of CBT. The rationale was that the program was more properly the role of the private sector and state and local governments. Although Congress restored funding for fiscal year 1984, the President continued to call for elimination of CBT in his budget requests for fiscal years 1985 through 1987. Congress restored funding each year until 1987, when it agreed with the Administration on a compromise cut of \$500,000 in CBT to end the attacks. The Administration reneged on the compromise and proposed for fiscal year 1988 to merge CBT and the Center for Fire Research at a level of one-half of their 1986 funding. Congress restored their funding at the reduced 1987 levels and kept the centers independent. The Administration proposals for reductions and the Congressional restorations continued for fiscal years 1989 and 1990.

CBT survived Administration proposals for its elimination because of strong support before Congress from the pri-

vate sector and state and local governments. Its work on failure investigations, measurements for thermal insulation, quality assurance for construction materials laboratories, and many other topics, was cited as evidence that it fulfilled important needs that could not otherwise be met.

The proposals for elimination or reduction allowed neither cost of living increases nor new initiatives for CBT's directly appropriated funding, and other agency funding was constrained by similar reductions in other agencies' funding. In order to remain effective, CBT responded to the financial constraints by narrowing scope as it cut staff. By 1986, work had been terminated in acoustics, architecture, economics, electrical distribution systems, environmental psychology, foundations, geotechnical engineering, plumbing, and solar energy. However, other programs were increased to respond to important needs: alternatives to the refrigerants threatening the ozone layer, automatic controls of building service systems, computer integrated construction and indoor air quality.

Recruiting new staff, whether entry level or mid-career, was difficult while the Center was under attack by the Administration. Indeed, many valuable people left either voluntarily or involuntarily. But, staff morale stayed strong; people were proud of their work and the public support for it highlighted by testimony in Congressional hearings. Productivity

was high and the evident reason for continued existence of the Center.

However, staff attitudes were defensive, and it would require a conscious effort to break away from a "bunker mentality" to take advantage of the opportunities the 90s offered to NIST and its Building and Fire Research Laboratory.

5.2 1981

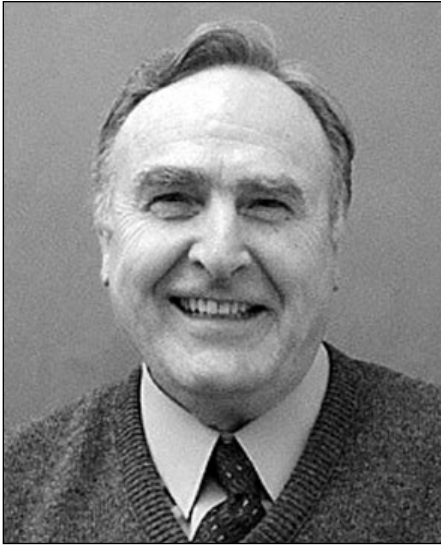
The National Construction Industry Council, an umbrella organization of trade and professional associations, was strongly concerned with lagging or declining construction productivity, and met with the Undersecretary of Commerce on November 27, 1979, to request support in technology in enhancing construction productivity. In response, CBT focused substantial efforts on technologies for improvement of the productivity of construction and of constructed facilities. Ongoing work in lifecycle costs and benefits, rehabilitation standards, plumbing systems performance and materials durability supported more productive construction, and acoustics and lighting supported more productive buildings. New work was proposed in computer integrated construction, building control systems, productivity measurements, equivalency systems for regulatory approval, concreting technologies, excavation, soil stabilization and materials handling. Although new funding was not received for many years, the productivity need was strong and work was

begun, through reprogramming, in computer integrated construction and building control systems.

Even prior to the election of November 1980, NBS requested that five positions be cut in CBT. Subsequent to the election with the preparation of the last Carter Administration budget, the assigned cut grew to 20 positions. When the Reagan Administration assigned reductions to NBS in February 1981, CBT's share grew again to 49. Department of Energy funding was reduced by 1.3 million dollars; major cuts would have been required for fiscal solvency alone. In total, CBT staff was reduced by about one-third.

CBT decided, with direction from NBS and NEL, to reduce its scope so that the remaining programs would be strong. The Environmental Design Research and the Building Economics and Regulatory Technology divisions were abolished. The Building Materials Division was split from the Structures and Materials Division to give CBT four divisions: Structures, Building Physics, Building Equipment and Building Materials. Applied Economics was transferred, with reduced staff, to the Center for Applied Mathematics, and groups in Architectural Research, Building Safety, and Building Rehabilitation Technology ceased to exist.

Geoffrey Frohnsdorff became chief of the Building Materials Division and held this position until his retirement in 2001. His unrelenting focus was to



Geoffrey Frohnsdorff, chief CBT Building Materials Division.

make more predictable the performance of building materials over their life cycle. He overcame much adversity in the initial lack of NBS funding for building materials research by working patiently and effectively with leaders in the scientific community, industry, NBS and other federal agencies to define and fund needed programs of research. He recruited and developed young scientists and engineers to bring his division to international leadership.

NBS director Ernest Ambler was uncomfortable with research in architectural and behavioral sciences areas as remote from the physical sciences and engineering measurements that he felt constituted the core of NBS, and susceptible to imprecision and questionable results that would be harmful to NBS' reputation. John Lyons and both James and Richard Wright had supported these areas of work as important for achieving CBT's objectives, but management's direction was clear. John Eberhard, as a consultant to CBT, was very helpful to staff seeking new jobs, prior to his own move in July 1981 to become executive director of the National Academies' Building Research Advisory Board.

All was not losses. Appliance efficiency staff and Department of Energy projects were transferred to CBT as the Center for Consumer Products Technology was eliminated, and the Construction Materials Reference Laboratory was transferred to CBT from the NEL Office of Engineering Standards.

It was vital to inform policy makers in the new Administration of the importance of construction productivity and the need for cooperation between industry and government to achieve it. Charles E. Peck, Executive Vice President, Owens-Corning Fiberglas Corporation, worked with Richard Wright to organize a Conference on Research for Building Construction Productivity on June 2, 1981, with sponsorship of the Construction Action Council of the Chamber of Commerce of the United States [1]. Keynote speakers were Joseph Wright, Deputy Secretary of Commerce, and John Dunlap of Harvard University. Technical presentations were made on measurement of productivity by professors Robert Logcher and David Kresge of MIT, reduction of construction duration by Joseph Newman of Tishman Research Corporation, reduction of risks of failure by Richard Marshall of CBT, computer-integrated construction by professor Steven Fenves of Carnegie Mellon, and productivity in the completed building by architect Ezra Ehrenkrantz.

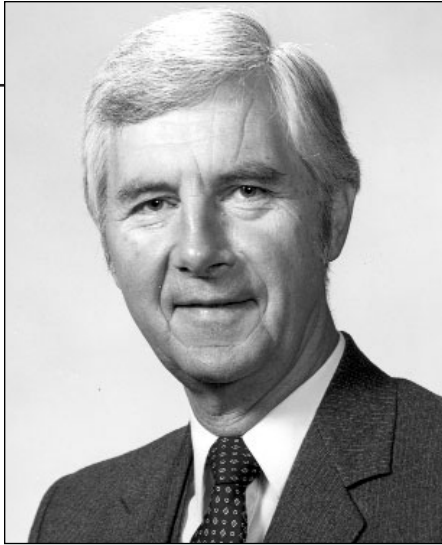
Consensus was reached on six primary research topics: micro measures of

productivity to assist in decision making, macro measures of productivity to assist in understanding industry trends, extending computer applications to all phases of construction decision making, expediting the regulatory process, relating occupant/user productivity to building design, and improving knowledge of the physical properties of buildings. The private sector should take the initiative to formulate and conduct research, with government supporting and conducting some research.

The Conference gave CBT good guidance, industry partners and bases for developing its research program, but, as events would show, did not lead to Administration support. In fact, Joseph Wright became a leader of the President's Office of Management and Budget as it locked into four successive years of proposals for the elimination of CBT, and three more for its halving.

Important results were achieved in spite of the tumult of staff cuts and reorganization. The innovative One Meter Guarded Hotplate went into service to provide reference samples of thick insulations needed by the insulation industry to meet Federal Trade Commission requirements for insulation labeling.

The only specific milestone in the President's plan for the National Earthquake Hazards Reduction Program was met when CBT synthe-



Edward Pfrang, chief CBT Structures Division.

sized and published the Draft Seismic Standard for Federal Buildings. The Life Cycle Costing Manual for the Federal Energy Management Program was published to allow federal agencies to comply with energy conservation legislation and Executive Order 11912.

Arthur Rubin's and Jaqueline Elder's hard cover, attractive *Building for People* was printed in 1981. It was dedicated to Reece Achenbach as "an engineer who designed and created a research environment which nurtured and fostered the growth of a new discipline." Its purpose was to acquaint the practicing architect and student to the potential contributions of the social sciences to the solution of building problems. It focused on the need to understand man/environmental relationships rather than making design recommendations or compiling knowledge. It was poignant to issue this thoughtful manifesto for man/environmental research at the time such research was being eliminated from NBS programs. But as the work notes, the research record did not show clear cut solutions to man/environmental problems.

On July 17, 1981, The Kansas City Hyatt Regency Hotel skywalks collapsed during a dinner dance killing 114 participants. Edward Pfrang, chief of the CBT Structures Division, immediately was sent to Kansas City to begin informally the investigation needed to understand the physical causes of the collapse. The official request to investigate came from Senator Thomas Eagleton on July 20, 1981. The skill and celerity with which Pfrang and his colleagues dealt with the technical, legal, political and publicity challenges surrounding the investigation probably was the single most important factor in the successful defense of CBT and the Center for Fire Research against the subsequent Administration efforts to eliminate these programs. Pfrang was outstanding for his imagination, forcefulness, and comfort with conflict where he showed extraordinary ability to think on his feet.

David Didion received the Silver Medal of the Department of Commerce for his research in development of more efficient test methods for the seasonal efficiency of heat pumps and air-conditioners. Edward Prang received the Silver Medal for his leadership in advancing performance criteria for housing.

5.3 1982

At the beginning of the fiscal year in October, as part of a budget reducing exercise imposed by the Department of Commerce, the NBS Director pro-

posed to cut CBT's directly appropriated funding by about 40 percent, but this cut was not accepted by the Secretary of Commerce. Indeed, in March, Secretary Baldrige gave Director Ambler an "A" for the Bureau's successful investigation of the Kansas City Hyatt Regency skywalks collapse. However, budget pressures did not end. In July, CBT was visited for a day by two mid-level executives from industry, who were without research experience but, under the auspices of the Grace Commission, were exploring opportunities to reduce the federal government. In September, the Grace Commission recommended elimination of CBT - its work should be funded by industry and performed in universities. The Department of Commerce's recommendations for the 1984 budget were to eliminate the Center for Fire Research and to cut from CBT's budget \$100,000 that had been devoted to solar energy research.

Congress showed direct interest in CBT's work. In February, the House Science and Technology Committee invited testimony on fire and earthquake research for the Federal Emergency Management Agency, and in August the House invited testimony on structural failures investigations.

Charles Thiel, who had been a leader in planning and implementing the National Earthquake Hazards Reduction Program (NEHRP) in his work at the National Science Foundation, on detail to the White House, and in the establishment of the

Federal Emergency Management Agency left the latter agency to join the private sector. Richard Wright succeeded Thiel as chairman of the Interagency Committee on Seismic Safety in Construction and represented NBS in the planning and management of the NEHRP.

Work on the Kansas City Hyatt Regency skywalks collapse was completed. Edward Prang and his colleagues were much involved in disseminating the findings and working with industry to improve quality in construction and avoid future failures from inadequate design and review of design. The Occupational Safety and Health Administration in April asked CBT to investigate the collapse of a highway overpass under construction. The National Academies' Evaluation Panel for CBT advised development of guidelines for CBT's involvement in disaster and failure investigations to avoid excessive involvement in investigations.

David Didion and his colleagues began studies of the performance of binary refrigerant mixtures in the refrigeration cycle. This work was motivated by desire to improve the efficiency of the refrigeration cycle, but subsequently became the basis for finding alternatives to the refrigerants harming the ozone layer. The National Academies' Evaluation Panel for CBT suggested that the staff return to programs more closely associated with CBT's goals, but CBT persisted.

Clinton W. Phillips, who had begun work as a technician with the CBT predecessor organization in the 40s and had risen to lead work on modular, integrated utility systems for buildings, was elected President of the American Society of Heating, Refrigerating and Air-Conditioning Engineers. Richard Marshall and Edward Pfrang received the Gold Medal of the Department of Commerce for their leadership of the investigation of the physical causes of the collapse of the skywalks of the Kansas City Hyatt Regency Hotel - the worst building accident in U.S. history. Richard Wright received the Gold Medal for his leadership of the restructuring of CBT without diminution of the effectiveness of the remaining staff. Geoffrey Frohnsdorff received the Silver Medal of the Department of Commerce for his leadership in the development of national standards for blended cements to improve cement performance and allow recycling of fly ashes and blast furnace slags. H.S. Lew received the Silver Medal for his leadership in national standardization for construction safety.

5.4 1983

1983 was the first and critical year of the Administration's efforts to obtain Congressional approval for the elimination of the Center for Building Technology.

In November of 1982, CBT was selected by NBS for review by the Inspector General of the Department

of Commerce "to determine whether officials of CBT are managing and using their resources economically and efficiently and whether the officials are complying with the laws and regulations concerning matters of economy and efficiency." In the Inspector General's report to the President of the Senate and the Speaker of the House [2] CBT received an extraordinary, entirely positive evaluation:

The Inspector General reviewed building research activities of the National Bureau of Standards' (NBS) Center for Building Technology (CBT) and found that CBT test and research projects were effectively meeting user needs.

CBT is a comprehensive building research laboratory whose staff produce technical bases for building performance criteria and measurement technology to assess building performance. CBT fills key building research roles that would not otherwise be done. Both government and industry have benefited from CBT because of its high quality work, technical competence and responsiveness. CBT also is highly respected for its objectivity: unlike most laboratories, CBT is not oriented toward support of a specific industry or product and thus cannot be accused of having any special axe to grind.

We found that both government and industry rely on CBT because:

- *It has provided the research necessary to develop new criteria and performance standards to reduce product costs and improve performance of building materials.*

- *It has a leadership role as well as the resources to serve the various segments of the fragmented building community.*
- *Its noncompetitive relationship with other Federal agencies and industry has combined with its technical competence to help CBT do a commendable job.*

We found it particularly interesting and indicative that not one of the private or university laboratories whose staffs we interviewed supported the elimination of CBT - even though this action doubtless would give them substantial additional research contracts.

We concluded that CBT is an unbiased source of building research information and measurement technology which has made important contributions to the Nation as a whole and in particular to the building industries. The building community has depended on CBT to provide essential building research information that would not otherwise be available. We made no recommendations to CBT.

On February 22, 1983, the Subcommittee on Science, Technology and Space of the Committee on Commerce, Science and Transportation of the United States Senate held hearings on authorization of appropriations for NBS for fiscal year 1984. NBS Director Ernest Ambler dutifully testified for the Administration "that the private sector and state and local governments should support fire and building technology research programs." This perspective

was contradicted in testimony and statements from the chairman of the National Research Council's Evaluation Panels for NBS, the chairman of the Statutory Visiting Committee for NBS, the Mineral Insulation Manufacturers Association, the American Society of Civil Engineers, the U.S. Chamber of Commerce and the National Institute of Building Sciences. The report of the Committee [3] stated:

The Committee believes that research performed at CBT is vital to public health and safety, and is worthy of continued support. The Committee intends that NBS fund CBT at the FY 1983 level.

On March 22 and 23, 1983, the Subcommittee on Science, Research and Technology of the Committee on Science and Technology of the U.S. House of Representatives held hearings on authorization of appropriations for NBS for fiscal year 1984 (Ninety-Eighth Congress, first session). Chairman Walgren, Congressman Reid, and Subcommittee staff had visited NBS on February 14, just three days after a major snowstorm, to see ongoing work and laboratories in CBT, CFR and the automation program. John Lyons, director of the National Engineering Laboratory, was tasked to give the Administration's rationale for elimination of CBT, but he also described its accomplishments. Testimony for the restoration of funds for CBT and CFR was presented by: Congressman Michael Barnes, who quoted many industry endorsements of the programs, professor Steven Fenves of Carnegie Mellon University, the

National Institute of Building Sciences, the Construction Action Council of the U.S. Chamber of Commerce, and the American Institute of Architects.

Letters in support of CBT and CFR were provided by: the Statutory Visiting Committee for NBS, the American Association for the Advancement of Science, the National Forest Products Association, the American Society of Civil Engineers, the Council of American Building Officials, the American Iron and Steel Institute, SMACNA, Brick Institute of America, the American Society of Heating Refrigerating and Air-Conditioning Engineers, the United McGill Corporation, and the Asphalt Roofing Manufacturers Association. The restoration of CBT also was requested by: the American Association of State Highway and Transportation Officials, Professor Steven Kendall of the University of Colorado, the Atlantic Cement Company, the Illuminating Engineering Society of North America, Richard Berkely, mayor of Kansas City, MO, Ernst Fuel and Supply Company, Kalamazoo Ready-Mix Concrete Company, the Transit Mix Concrete Company, the Material Service Corporation, the National Concrete Masonry Association, the National Gypsum Company and the Conrock Company.

The Report of the Committee [4] stated:

In the area of building research, NBS provides a vital role in providing the tech-

nical basis for codes and standards which are the heart of our building system in the United States. In addition, the Center for Building Research provides a basis for NBS to develop significant expertise in the area of building technology and thereby it is able to well serve the needs of the public when expert, third party investigations are requested following a building failure such as the Kansas City Hyatt Regency walkway collapse. These investigations, besides providing local governments and local officials with a very much needed service, also provide NBS with guidance for research efforts. The bill provides a minimum of \$4.5 million for this center.

The House floor providing an increase in funding for CBT did not prevail in conference with the Senate, but CBT was restored in the 1984 budget at the 1983 level of funding. In spite of the outstanding support from the building community, this amounted to a cut in the program by the rate of inflation (4.3 percent by the Consumer Price Index).

CBT's Long Range Plan was updated and retitled Building Research for the Computer Age. Applications of advanced computation to buildings' systems and to the building process were anticipated to change radically:

- What we build - buildings will be automated to respond to dynamic human needs and environmental conditions,
- How we build - processes of design and construction will change to exploit potentials of computer-aided

design and automated manufacture and construction,

- Who builds - roles in the building process will change as advanced computation and automation make some skills obsolete and require other new skills.

Program objectives were grouped in seven tasks:

1. Computer integrated construction
2. Structural safety
3. earthquake hazards reduction
4. building physics
5. building equipment
6. quality of building materials
7. cement hydration

Computer integrated construction is a vision for seamless, automatic, flow of information among all participants throughout the whole life cycle of a constructed facility (planning, design, manufacture, construction, operation, maintenance, renewal and removal). Research in computer integrated construction had begun with modeling of standards as networks of decision tables, developing computer aids to assist in the formulation and expression of standards, and techniques for interfacing machine representations of standards to programs for computer aided design. In 1983, CBT's Computer Integrated Construction group began to collaborate with the Center for Manufacturing Engineering in support of the Architecture, Engineering and Construction industries group working on the Initial Graphics

Exchange Standard of the American National Standards Institute.

Cooperative efforts in computer integrated construction were discussed with other federal agencies and the private sector under the auspices of the National Academies' Advisory Board on the Built Environment for which John Eberhard was executive director. Richard Wright presented a keynote address on computers in buildings, building and building research at the triennial congress of the International Council for Research and Innovation in Building and Construction (CIB) formerly the International Council for Building Research, Studies and Documentation in Stockholm. CIB created working commissions for international collaboration in integrated computer aided design and in control of building service systems in which CBT researchers played leading roles.

CBT's work continued to be conducted in four divisions: structures, building physics, building equipment and building materials. Edward Pfrang left leadership of the Structures Division to become executive director of the American Society of Civil Engineers; Charles Culver became chief of the Structures Division. Charles Culver's philosophy was "results speak for themselves" in his work as program manager for earthquake hazards reduction, deputy director of CBT and chief of the Structures Division.



Charles Culver, chief, Structures Division

Preston McNall left leadership of the Building Physics Division because of illness; Tamami Kusuda became its chief. Kusuda had achieved an international reputation as the leader in the computer modeling of the thermal performance of buildings. James Gross became the deputy director of CBT.

James Gross represented CBT at the American Society of Civil Engineer's Structures Failure Conference which placed strong emphasis on better defining responsibilities during the development, design and construction of projects. Richard Wright was elected president of CIB for the period 1983-86. He also led the American Society of Civil Engineers' November 1982 Productivity Roundtable and September 1983 Productivity Workshop.

5.5 1984

Again, CBT and CFR were proposed for elimination in the President's request for the fiscal year 1985 budget. The rationale was that these programs are more properly the role of the private sector and of state and local governments. Again, private sector organi-

zations and the National Conference of States on Building Codes and Standards testified that these programs are needed and cannot be funded by private industry or state or local governments. Congress concluded [5] "the research performed at CBT is vital to public health and safety, and is worthy of continued support." Funding was restored at the 1984 level - another cut by the amount of inflation (3.7 percent).

CBT continued in budget problems. NBS decided not to propose any budget increases to the Department of Commerce for CBT for fiscal year 1986. Before the year end, the President's Office of Management and Budget informed NBS that CBT and CFR again would be proposed for elimination in the President's budget request for fiscal year 1986.

Additional Congressional hearings on structural failures resulted in legislation authorizing NBS to investigate important structural failures at its own initiative. For unrelated reasons this legislation was pocket vetoed by the President, but became law subsequently.

CBT's strategy from its strategic planning was to build its capability in computer-integrated construction at the same time as it strengthened its laboratory-based performance prediction and measurement programs. However, both directly appropriated funding and sponsored research were essentially static in current dollars and declining in real dollars. Budget problems made

it difficult to recruit strong staff.

Human and financial resources were focused on the most significant issues and best technical opportunities. Knowledge based expert systems were identified as the emerging successor to paper standards as the principal vehicle for delivery of CBT research to practice. Training in expert systems was organized for interested staff and prototype expert system projects were funded in the divisions.

The Interagency Committee on Seismic Safety in Construction (with NBS chair and secretariat) decided to proceed with development of a seismic standard for new federal buildings and to draft an executive order for its implementation in federal and federally assisted new building construction. The federal standard would be based on the Recommended Provisions for Development of Seismic Regulations for New Buildings being developed by the Building Seismic Safety Council with financial support from the National Earthquake Hazards Reduction Program (NEHRP), and could be used if the voluntary national standards and model building codes did not adopt the NEHRP Recommended Provisions in form and substance suitable for federal use.

CBT added important new laboratory facilities:

- Tri-Directional Structural Testing Facility - a unique computer controlled apparatus capable of applying loads or displacements in six degrees of freedom (three transla-

tions and three rotations) to large scale structural components to simulate conditions in earthquakes or other extreme environments.

- Universal Testing Machine - added a reaction wall to the 53 MN testing machine to allow combinations of vertical and lateral loading to large specimens.
- Calibrated Hot Box - for precise measurement of air, heat and moisture transfer in full scale building wall sections, with doors and windows, over a wide range of climate conditions.

Emil Simiu was named Federal Engineer of the Year 1984 by the National Society of Professional Engineers for his leadership in wind research, contributions to the improvement of standards for wind loadings, and co-authorship of the nation's leading reference book on wind engineering. He also received the Department of Commerce Silver Medal in recognition of these accomplishments.

5.6 1985

Again, CBT and CFR were proposed for elimination in the President's budget request for fiscal year 1986. Again, the rationale was that these programs are more properly the role of the private sector and of state and local governments. It seemed that the Administration wanted to show sustained commitment to reducing the size of the federal government and required NBS to offer its sacrifice.

And, NBS had learned that it was safe to offer CBT and CFR for cuts, and that the exercise did not require imperiling other programs.

It was tedious to again supply information for testimony to private sector collaborators when Congress seemed resolute in its support for building and fire research, but existence is a serious business and had to be top in priority. Testimony from collaborators was strong. ASTM stated to the House of Representatives on February 28, 1985:

The work of the Center for Building Technology and the Center for Fire Research are essential to the development of consensus standards for many, many ASTM committees, and this work becomes an integral part of probably one of the most important regulatory processes in America - Building Codes and Life Safety Codes.

At the same hearing, the National Institute of Building Sciences testified:

- *The Centers for Building Technology and Fire Research are essential parts of an overall framework intended to improve the quality of the built environment. --- the nation's construction industry has come to rely on these centers for thorough and objective data, and for services available nowhere else. --- the programs at CBT and CFR should be continued and are best supported and fostered by non-proprietary interests. --- Our belief is that these centers help stimulate new technological developments and speed their use in design and construction practice, as a result of open public disclosure, where new information and ideas may be fur-*

ther advanced by innovative individuals and corporate interests.

The American Society of Heating, Refrigerating and Air-Conditioning Engineers wrote to the House of Representatives on March 5, 1985:

The two centers under discussion have produced research which finds its way promptly into the private sector for the benefit of the general public, business, industry and all levels of government. --- More than one-third of the ASHRAE standards are based in whole or in part on information developed at the Bureau, further evidence of government agency-private sector cooperation.

The American Society of Civil Engineers wrote to the House of Representatives on March 6, 1985:

CBT is the only research program that integrates complex technical issues affecting the vast building industry. Despite the fact that it amounts to about 10 percent of the GNP, and that almost two-thirds of the nation's wealth is invested in constructed facilities, the building industry is very fragmented. CBT provides a uniform base of information, and serves as a unifying force for the entire industry. Because of the industry's size and diversity, no part of the private sector can duplicate these efforts or adequately distribute the findings on its own. This interdisciplinary laboratory also integrates complex technical issues in a way that more narrowly-focused proprietary research and development cannot.

The National Conference of States on Building Codes and Standards testified

at the Senate hearing on March 8, 1985:

1. *The National Bureau of Standards' Center for Building Technology and Center for Fire Research continue to provide the nation's states and local governments with invaluable building and technological research which the state and local governments depend upon to help them adopt and enforce modern building and fire codes which provide for their public's health and life safety in new and existing buildings.*
2. *That the states individually or working together cannot and will not be able to build, staff, and fund or contract for such research should the Centers for Building Technology and Fire Research cease to operate.*
3. *That even if the states were able to build, staff, and fund or contract for such research, that each state would duplicate the research programs of the other states in the area of building and fire safety, resulting in a large and inexcusable waste of taxpayers' funds.*

Congress restored funding for CBT and CFR for fiscal year 1986 and provided specific authorization for future investigations of structural failures:

The National Bureau of Standards, on its own initiative, but only after consultation with local authorities, may initiate and conduct investigations to determine the causes of structural failures in structures which are used or occupied by the general public.

The President's Office of Science and Technology Policy, acting upon a recommendation from the National

Academies' National Research Council, requested CBT to initiate a design study for a National Earthquake Engineering Experimental Facility with exploration of research needs for the facility. The goal was to develop a world class, national user facility to provide the data and understanding necessary for rapid improvements in the design and construction of earthquake resistant structures. The study was funded by the Federal Emergency Management Agency and the National Science Foundation.

CBT worked with the Center for Manufacturing Engineering to explore with owners, designers, contractors and manufacturers the potential and research needs for robotics in construction [6]. Automated construction site metrology was seen as a higher priority than robotic equipment. The value of the metrology would be high for locating equipment and materials and documenting what actually was built, even if there were no automatic equipment to control.

The CBT plan for 1986-1990 addressed opportunities and challenges for international competitiveness that information technologies bring to the building community. Areas of work included:

1. Advanced measurements for building diagnostics and quality assurance.
2. Performance modeling and prediction technologies.
3. Automation of building operating systems

4. Robotics in construction.
5. Information interfaces for integrated computer-aided design, construction and operation.
6. Technologies for standards and expert systems.

The National Academies' Panel for Building Technology [7] agreed that the strategic direction was sound but was skeptical about the Center's ability to address artificial intelligence and computer-aided construction processes with available resources and did not want resources diverted from ongoing programs. The Center persisted in research on measurement and modeling bases for information technologies in construction, but had to limit its work in expert systems to exploring applications of technologies developed elsewhere.

Under the direction of Secretary of Commerce Herbert Hoover in the 1920s, NBS had undertaken the secretariats of important national voluntary standards to assist in their development and maintenance. One of these became American National Standards Institute Standard A.58.1 *Minimum Design Loads for Buildings and Other Structures*. However, NBS management now desired to focus its work on measurement technology, rather than standards administration. After 60 years at NBS, the secretariat of A.58.1 was transferred to the American Society of Civil Engineers (ASCE) in 1984. Bruce Ellingwood, who had served as the standard's secretary, and had received the ASCE's highest award,

the Norman Medal, in 1983 for two papers that he co-authored on probability-based limit states design for the standard, left CBT in 1986 to become professor of civil engineering at The Johns Hopkins University.

Another effect of advancing information technologies was the elimination of the Center's word processing center in order to optimize deployment of clerical staff. It had been established to achieve the same objective in 1977. Increasing availability of personal computers made it possible for manuscript preparation to be handled principally by the researchers and clerical staff in the groups. The Structures Division eliminated its Geotechnical Group. With staff and funding attrition, it was infeasible to maintain this competence.

On a higher note, David Didion's research on mixed refrigerants showed achievement of a 15 percent increase in heat pump capacity at low temperatures which promised substantial energy savings by reducing needs for electrical resistance backup heating.

5.7 1986

Again the Administration proposed elimination of CBT and CFR in its budget request for fiscal year 1987, and again the building and fire communities strongly supported the continuation of the centers. Congress received testimony or letters supporting CBT and CFR from ASTM, American Institute of Steel Construction, American Society of

Civil Engineers, National Conference of States on Building Codes and Standards, National Institute of Building Sciences, Portland Cement Association, National Society of Professional Engineers, and USG Corporation. Additional support for CBT was received by Congress from American Society of Plumbing Engineers Research Foundation, American Concrete Institute, Ayres Consulting, Carnegie Mellon University, Dow Chemical, ETL Testing Laboratories, Honeywell Corporation, Institute of Noise Control Engineering, Lighting Research and Education Fund Committee, Mineral Insulation Manufacturers Association, National Ready Mixed Concrete Association, National Roofing Contractors Association, New Jersey Institute of Technology, Ross Meriwether and Associates, and Ryland Group. Also, the Congressional Research Service of the Library of Congress prepared a report for the House Committee on Science and Technology [8] which concluded "Many of CBT's current functions appears to be consistent with the Administration's stated views on the proper role of the Federal government with respect to both the private sector and State and local government."

The outcome of the budget process, however, was different - a compromise. To end this cycle of proposed eliminations and restorations, the Congress and the President's Office of Management and Budget agreed that

CBT's and CFR's funds for fiscal year 1987 each would be reduced by \$500,000, and there would be no further cuts proposed for the remaining budgets (1988 and 1989) to be proposed by the Reagan Administration. The cuts occurred. However, the Administration subsequently reneged on the agreement and proceeded to propose additional reductions for fiscal years 1988 and 1989.

The consequences of the cuts included termination of research in acoustics and plumbing and substantial reductions of research in lighting.

The reductions in directly appropriated funding for 1987 were exacerbated by projected reductions in funding from the Department of Energy of 1 million to 1.5 million as energy conservation funding would be reduced about 40 percent and solar energy funding terminated. Therefore, a reduction in force of sixteen positions was decided upon at the end of fiscal year 1986. However, the National Appliance Energy Conservation Act of 1986 called for NBS to develop test procedures for determining the annual operating costs and energy consumption of eleven specified appliances. The Act assured continuity of funding from the Department of Energy for this work.

The Continuing Appropriations legislation for fiscal year 1987 called for NBS to conduct an independent investigation of the structural integrity of the new U.S. embassy office building

in Moscow. The report, including an assessment of the existing structure and recommendations and cost estimates for correcting any structural flaws and construction defects, was required to be transmitted to Congress by April 15, 1987. Funding was provided by the Department of State.

At the request of Congressman Sherwood Boehlert, NBS, ENR (the principal weekly journal of the industries of construction), and SUNY-Utica College of Technology sponsored a Roundtable on Construction Technology for the 90s. It was the cover story in the August 4, 1986, ENR. Twenty-five participants, representing owners, designers, contractors, regulators, labor, manufacturers, educators and researchers, identified critical technical issues for the industries of construction:

- Information interface technologies supporting the automatic exchange of information between all participants in a construction project and conducive to open systems of computing hardware and software for the participants.
- Automated communications and control systems for constructed facilities (such as “smart houses” and “intelligent buildings”) that are reliable, break down gracefully, and are open for partial upgrading and to innovations by small manufacturers.
- Low-risk test beds for innovations such as trials of novel materials and systems in the construction programs of federal agencies.
- Informing public policy makers,

such as regulators, of the technical bases for sound public policy decisions.

- Learning from and applying to U.S. practices the accomplishments of foreign research and development.
- The CBT program responded to all these issues.

CBT conducted the first full-scale laboratory test of a bridge column subjected to simulated seismic loading. The specimen, fabricated in accord with California State specifications, was 13.7 m tall and weighed more than 200 t. It resisted more than ten cycles of inelastic deformation exceeding six times the yield deformation, and showed how seismic resistant construction could be made more economical. Project leader William Stone and division chief Charles Culver made extraordinary efforts to conduct the test on a schedule convenient to a Congressional audience and the test received front page coverage in the Post.

The Interagency Committee on Seismic Safety in Construction (ICSSC), chaired by Richard Wright, developed the proposed executive order on seismic safety of federal and federally assisted construction, which was then approved by the Interagency Coordinating Committee of the National Earthquake Hazard Reduction Program and transmitted to the President's Office of Management and Budget. There it went through many cycles of review and was reduced in scope to new federal and federally

assisted or regulated buildings, and was ready for issuance when the Loma Prieta earthquake in 1989 demonstrated its need to policy makers.

James Clifton and Lawrence Kaetzal produced CBT's first major expert system DURCON (durable concrete) in cooperation with the American Concrete Institute Committee on Durability of Concrete.

CBT, in cooperation with the Building Research Board of the National Research Council and the International Union of Bricklayers and United Craftsmen, hosted the CIB 1986 Triennial Congress. Over 500 researchers and practitioners shared research findings and addressed issues of advancing building technology: for the computer age, for shelter for the homeless in developing countries, and for translating research into practice. Richard Wright was president of CIB, Noel Raufaste led the organizing committee, and James Clifton chaired the program committee. Richard Wright also was elected president of the Liaison Committee of International Civil Engineering Organizations for 1985-87. Any joy in these recognitions of CBT's international leadership was squelched by the simultaneous reductions in loyal and productive staff required by CBT's budget cuts.

E.V. Leyendecker received the Silver Medal of the Department of Commerce for his technical support of the consensus development of Recommended Provisions for Seismic

Regulations for New Buildings by the Building Seismic Safety Commission.

5.8 1987

In its continuing attacks on appropriated funding for CBT and CFR, the Administration proposed for the fiscal year 1988 budget to merge the centers and fund the combined center at a level of \$5 million. This would have been a fifty percent cut in directly appropriated funding. Community support for the centers remained strong and their funding was authorized and appropriated by Congress at the “compromise” level with allowance to receive adjustments to base (their pro rata share of appropriations intended to cover inflation). Moreover, the Department of Commerce refused to consider a proposal to increase CBT’s funding for construction automation for fiscal year 1989 as inconsistent with Administration policy.

As a result of reductions in its funding for solar energy research, the Department of Energy (DOE) eliminated support of solar energy in buildings research in CBT. CBT had a strong record of success in solar energy research including test methods for solar thermal equipment, minimum property standards allowing federally insured mortgages on solar-equipped homes, and organization of and contributions to ASTM and ASHRAE standards programs for solar energy components and systems. However, the national laboratory managing the

building solar program for the DOE gave its own work priority over CBT’s.

When DOE was established in the 70s, NBS decided against undertaking program management for DOE because it would be a substantial diversion of effort from research. Was NBS wrong? Probably not. While CBT’s research funding from DOE suffered from preferential funding of their own laboratories by program managers at national laboratories, program management would have been a severe distraction from the NBS mission and an NBS role in program management would have been difficult to maintain in competition with DOE national laboratories.

Because of the reductions in research for the Department of Energy, the Building Physics Division and the Building Equipment Division were combined to form the Building Environment Division under the leadership of James Hill. Hill superbly managed the necessary reductions in force to retain the most productive and promising research staff - for which he received the Presidential (of the U.S.) Meritorious Executive Rank Award in 1988. Tamami Kusuda retired as chief of the Building Physics Division to complete his career as the world’s pioneer in computer methods for analysis of building thermal performance.

CBT’s work on refrigerant mixtures proceeded very well. Laboratory stud-

ies demonstrated a 32 percent improved efficiency for a heat pump operating at steady state conditions in the cooling mode compared to a heat pump under the same conditions using R-22 as the working fluid. David Didion received the Gold Medal of the Department of Commerce and the Applied Research Award of NBS for these accomplishments. Moreover, work began on finding efficient substitutes for the refrigerants harmful to the ozone layer. In Indoor Air Quality, CBT developed and verified a model to predict indoor contaminant levels as functions of emission, dilution and intra-building air movement (the first model not to consider a building as one, large, uniform space).

Under the leadership of Nicholas Carino, CBT completed its study of the structural integrity of the new U.S. embassy office building in Moscow, by the Congressionally imposed deadline of April 15, 1987, and for about half of the funding allowed by Congress. The investigation identified important structural defects and defined remedial measures to correct them. While important, these structural defects were modest in scale and fully correctable. There were no perceptible disagreements with these recommendations; in the 90s the building was repaired (with the upper stories, where information security concerns were greatest, removed and replaced) and put into service. Carino received the Silver Medal of the Department of

Commerce for his leadership of this investigation.

For the Occupational Safety and Health Administration (OSHA) and under the leadership of Charles Culver, CBT investigated the physical causes of the collapse of the L'Ambience Plaza apartment building in Bridgeport, Connecticut on April 23, 1987, which killed 28 construction workers. In contrast to earlier CBT structural failure investigations, there was substantial professional controversy about the CBT findings, but they stood up well over several years of discussions in professional conferences and papers. OSHA was pleased with the results and subsequently hired Culver to lead its new Office of Construction Safety.

This was the last of CBT's investigations of construction failures for OSHA. Under Culver's leadership, OSHA conducted its own investigations. These investigations were high risk for NBS. Reports were due for release six months after the accident to be a basis for OSHA's legal actions. Could a sound determination of the physical cause always be so quickly accomplished? CBT succeeded for the Skyline Plaza Tower and Parking Garage in 1973, the Willow Island Cooling Tower in 1978, the Harbour Cay Condominium in 1981, the Riley Road Interchange Ramp in 1982 and the L'Ambience Plaza Apartment in 1987, and probably would have continued if requested and given proper authority and funding for thorough investigations. The investigations were important public service, a

valuable professional experience for staff and a distraction from CBT's research mission.

Mary McKnight, Jonathan Martin, Edward Embree and Dale Bentz won an IR-100 Award for their surface profilometer which uses infrared emissions to measure surface topography. Robert Mathey and James Clifton won the Lindau Award of the American Concrete Institute for their research on epoxy coated reinforcing bars to improve the service lives of concrete slabs exposed to deicing salts. This work was the basis for the development of the epoxy coated reinforcing industry.

5.9 1988

In its request to Congress for the fiscal year 1989 budget for CBT and CFR, the Administration proposed again to merge the centers and fund the combined center at a level of \$5 million. Again, the centers received strong support from the building and fire communities, and their funding was restored. The budget environment for CBT remained such that no request for increased funding for fiscal year 1990 was submitted by NBS to the Department of Commerce.

However, a budget initiative increase of \$250,000 for fiscal year 1989 was appropriated for research on replacements for the refrigerants that threaten the ozone layer. This increase was accomplished by budgeting the program in the for Chemical Engineering, which received an equal increase, even

though the initiative was led by David Didion and based on his pioneer work in CBT. Chemical Engineering studied the thermo-physical properties of alternative refrigerants and Building Technology studied their performance in the refrigeration cycle.

This was the first initiative increase in appropriated funds (beyond adjustments to base for inflation) received by CBT since the fiscal year 1974 initiative of \$400,000 for energy conservation. However, a doubling of both directly appropriated and other agency funding would have been required to return CBT to its level of effort in fiscal year 1980. CBT since 1974 annually had developed initiative proposals to respond to needs of the building community. Among the topics were technologies (measurements and test methods) for: earthquake hazard reduction, building rehabilitation, construction productivity, quality assurance and condition assessment, and computer integrated construction. These did not attract support of NBS management, in spite of industry demands and the importance of the industries of construction in the Nation's economy, CBT's national and international technical leadership, Administration initiatives and potential for Congressional support, seemingly because NBS management preferred to try for growth in other areas and disciplines.

The National Science Foundation established in February 1988, the Center for Advanced Cement-Based

Materials at Northwestern University, NBS, University of Illinois at Urbana-Champaign, University of Michigan and Purdue University were the other member institutions. NBS's participation in the planning and conduct of the Center was led by Geoffrey Frohnsdorff and James Clifton. The Center's thrust to make concrete a well characterized material of predictable performance was based substantially on the accomplishments of NBS's Cement Hydration Competence Project. The Center's long-term, fundamentally-oriented research allowed NBS and collaborators to make great contributions over the following 11 years.

NBS became the National Institute of Standards and Technology (NIST) on August 23, 1988, when the Omnibus Trade and Competitiveness Act of 1988 became effective. The Act provided for continuity of NBS functions, such as building and fire research, and added the Advanced Technology Program (ATP) to cost share high risk research with industry, and the Manufacturing Extension Partnership (MEP) to assist small and medium sized manufacturing companies. CBT staff were proud of being part of NBS and many were uncomfortable with the change in name, but both the ATP and MEP were seen as opportunities to collaborate effectively with the industries of construction. In later years, many companies developed ATP projects with which CBT collaborated. However, the MEP did not extend its

scope to consider construction contractors and builders as manufacturers even though the National Association of Home Builders, and other construction organizations, expressed interests in participating in MEP.

Through its participation in and leadership of CIB (Richard Wright was its past president and Programme Committee chairman) CBT became aware of the importance of the Single European Act calling for the free flow of goods and services within the European Community (EC) by 1992. At CIB's May 1988 Research Managers' Meeting, European members organized the European Network of Building Research Institutes (ENBRI) to participate in programs for standards, regulation, certification and testing which will make products and services acceptable in all the EC countries. These activities were anticipated to have substantial effects on U.S. industries of construction since the European standards could be barriers to the export of U.S. products and services, and since European firms working successfully in the larger European market would be better prepared to compete in the U.S. market.

In its update for 1989-1993 of its Long Range Plan, CBT organized its program by three focuses:

1. Quality Assurance and Condition Assessment technologies to improve U.S. competitiveness.
2. Computer-Integrated Construction technologies for the long range

technical leadership and competitiveness of the U.S. industries of construction.

3. Earthquake Hazard Reduction.

The first comprised almost 90 percent of the current level of effort. The latter two were developed separately because of high demand for program growth in these areas.

David Didion and Mark McLinden published *Quest for Alternatives: A Molecular Approach Demonstrates Tradeoffs and Alternatives are Inevitable in Seeking Refrigerants* in the December 1987 ASHRAE Journal, which described the systematic, CBT-developed approach to obtaining energy-efficient alternatives to environmentally-harmful refrigerants. The paper received ASHRAE's best paper award and the 1988 NIST Condon Award for expository excellence.

The Initial Graphics Exchange Specification (IGES) Version 4.0 standard was published with a new capability for exchanging tabular and relational data in addition to graphical data. The capability was developed and championed by the IGES Architectural, Engineering, and Construction Committee chaired by Kent Reed of CBT.

Emil Simiu was awarded by the NBS Director a competence project on chaotic structural dynamics to be conducted jointly by CBT and the Center for Computing and Applied Mathematics. Avoidance of chaotic

response is important for deep-water compliant structures, flexible space structures and robot arms, and other non-linear systems. Simiu also was appointed an NBS fellow based on his national and international leadership in wind engineering and structural dynamics.

Richard Wright was named Federal Engineer of the Year 1988 by the National Society of Professional Engineers (NSPE). NSPE cited CBT accomplishments in structural failure investigations, improvements of the refrigeration cycle and leadership in international building research organizations. Wright also received the President's Meritorious Executive Award for leadership of CBT. James Hill also received the President's Meritorious Executive Award for achieving outstanding accomplishments in the Building Environment Division at the same time that it was being substantially cut in staff. It seems remarkable that the President, who sought to eliminate CBT, also would recognize its managers for outstanding performance.

5.10 1989

The Administration's request to Congress for the fiscal year 1990 budget, the last prepared by the Reagan Administration, proposed again to merge CBT and CFR and fund the combined center at a level of \$5 million. The proposal also called for termination of the \$250,000 funding for alternative refrigerants. Congress again restored the funding for the fiscal year

1990 budget. Also, CBT and CFR directors discussed the programs with the new Bush Administration officials in the Department of Commerce and the Office of Management and Budget with the result that the cuts no longer were proposed for the fiscal year 1991 budget.

The 1989 Panel for Building Technology of the Board on Assessment of NIST Programs, in December 1988, suggested that CBT prepare a report on the international competitiveness of the U.S. construction industry. The report [9] was published in May 1989, and used to focus the CBT program and guide collaborations with other organizations. It was presented to: the Sixth International Symposium on Automation and Robotics in Construction (sponsored by the Construction Industry Institute), the Building Research Board of the National Academies, and the Hearing on R&D in Construction of the House Subcommittee on Science, Research and Technology. It recommended that the U.S. industries of construction work for open systems of technology for construction products and services to facilitate innovations. CBT's role would be to provide measurement and test methods for assurance of quality and acceptance of innovations.

The Building Seismic Safety Council (BSSC), since it was organized in 1979, had worked to review the Tentative Provisions for the Development of Seismic Regulations for Buildings published by the Applied Technology

Council, NSF and NBS in 1978, revise provisions appropriately, and conduct trial designs to test their usability, cost impact and technical validity. As a result of these studies, BSSC published the *National Earthquake Hazards Reduction Program Recommended Provisions for the Development of Seismic Regulations for New Buildings* (Recommended Provisions) in 1985, and with further studies published an updated version in 1988. When he became a member of the BSSC Board in 1989, Richard Wright noted that there were no ongoing efforts to incorporate the Recommended Provisions in the national standards and model codes even though these organizations were represented on the Board and were involved in the development of the Recommended Provisions. The BSSC and the Federal Emergency Management Agency (FEMA), which had sponsored the BSSC work, agreed that such efforts were appropriate. NBS, with FEMA's approval, reprogrammed funding it had received from FEMA for other technical studies to prepare proposed changes to the American Society of Civil Engineers' standard for design loads on buildings and to the Basic Building Code. These proposals were available when severe losses in the October 17, 1989, Loma Prieta California earthquake produced enhanced national concern for seismic safety and led to timely revisions in the ASCE standard and in the Basic Building Code used in the eastern U.S. and the Standard Building Code used in the southeastern U.S. The Uniform Building Code used in the western U.S., although it used a working stress approach different from that of the Recommended Provisions, also benefited from the BSSC studies in its revisions.

Reorganization of NIST was anticipated from the time of its creation in 1988, but the NIST Visiting Committee recommended that reorganization await the appointment of a new NIST director (Ernest Ambler had become acting Under Secretary for Technology in December 1988 and retired from government service in April 1989.) CBT and CFR management anticipated that their merger would occur and held joint meetings in fiscal year 1989 to gain mutual familiarity with their programs.

In the decade since its founding, the CBT Building Controls program had developed dynamic control system simulation techniques and measurement and test methods for sensors and for control algorithms to support open, intelligent, integrated and optimized building mechanical systems that give customers the reliability and economy resulting from independence from a single manufacturer. In 1989 to advance this work, Steven Bushby became secretary for ASHRAE Standard Project Committee 135 on Energy Monitoring Control System Message Protocol and chairman of its Application Sources Working Group which led in time to national and international open systems standards for building automation.

Under the leadership of CBT deputy director James Gross, CBT began work with U.S. standards organizations and industry to open global markets to U.S. construction products and services by: (1) developing an active U.S.

advocacy role in international standards activities, (2) establishing a coherent system for acceptance of innovative building products, and (3) improvement of the acceptance and quality assurance of products for which there are applicable international standards. To advance these objectives, Gross led a task force of the ANSI Construction Standards Board to plan its future functions and activities, led development of a five year plan for ASCE's Codes and Standards program, participated in a delegation of the Department of Commerce to discuss testing, certification and conformity assessment with the EC Commission, and served on the CIB Board and Programme Committee.

RILEM (the International Union of Testing and Research Laboratories for Materials and Structures) adopted as a technical recommendation for international standardization the Standard Practice for Developing Accelerated Tests to Aid Prediction of the Service Life of Building Components and Materials. The document was based on CBT research and Larry Masters of CBT led the ASTM and RILEM committees that developed the ASTM standard and the RILEM technical recommendation.

Nicholas Carino and Mary Sansalone developed the impact echo method for flaw detection in reinforced concrete structures which was independently assessed as having demonstrated applicability to flaw detection in thick and layered structures and the best potential for field use.



Hai Sang Lew, chief, Structures Division and leader of numerous post earthquake investigations.

George Walton completed AIRNET, a computer simulation model for airflows between rooms and through the envelope of a building. It was cited at an international air infiltration workshop as "the world's best and fastest ventilation model with a well-defined open structure suitable for widespread use."

H.S. Lew participated in the U.S. team studying structural performance of buildings in the December 1988 Armenian earthquake. The earthquake was particularly interesting for U.S. practice because of the exposure of modern pre-cast concrete buildings to strong shaking. Findings were reported to Congress and regional conferences on seismic safety and published by the Earthquake Engineering Research Institute. Dr. Lew, who had twenty-years experience at NIST as structural research engineer and group leader, became Chief of the Structures Division in December 1988 when Charles Culver transferred to OSHA to lead its Office of Construction.

Emil Simiu received the Gold Medal of the Department of Commerce for his studies of wind and wave effects on offshore structures - knowledge essential to oil recovery from deep water sites.

5.11 1990

The Loma Prieta, California earthquake of October 17, 1989, (sometimes called the World Series earthquake because it interrupted the start of a game at San Francisco and showed fans a real time view of the fires in San Francisco), had great effects on the National Earthquake Hazards Reduction Program (NEHRP) and NIST's work in NEHRP. The ICSSC (chaired by Richard Wright and with a NIST secretariat) immediately dispatched a multi-agency team led by H.S. Lew to investigate damages to structures and fires. The report made substantive recommendations to improve design and construction practices for buildings and lifeline structures and to mitigate damages to existing structures in future earthquakes.

On January 5, 1990, President Bush issued Executive Order 12699, Seismic Safety of Federal and Federally Assisted or Regulated New Building Construction, that NIST drafted and redrafted through reviews and approval by the ICSSC from 1984-86, and by the Federal Emergency Management Agency (FEMA), the White House and the federal agencies from 1986-90. The Order required that all new buildings constructed or lease-constructed for federal use must immediately be designed and constructed in accord with appropriate seismic standards. By January 5, 1993, similar requirements applied to all federally supported or regulated new building construction, e.g., homes financed with FHA or VA

mortgages. Building code organizations welcomed the Order. The work to develop the NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings, test them in trial designs, and translate them to standards and code language made the Order feasible, and its existence provided an incentive to State and local governments to adopt and enforce up to date building codes. The sustained financial and political support of FEMA deserves primary credit for the development of the Recommended Provisions and the Order. NIST provided sustained technical support and research, the National Science Foundation provided the principal structural research support over many years for the knowledge base, and the U.S. Geological Survey (USGS) provided the knowledge base for definition of the earthquake hazard. The Order marked a real success story for NEHRP.

In October 1989, Congress made a supplemental appropriation to support NEHRP studies of the earthquake. NIST received \$2 million available over two years which it used to hire excellent additional staff, including Albert Lin, Harry Shenton and Diana Todd, and strengthen its research program. However, it was not possible to convert this to an increase in base funding and the financing of the program became difficult in fiscal year 1993.

The enhanced earthquake interests led to some tensions in NEHRP.

There was an effort to replace FEMA with USGS as lead agency, in which NIST did not get involved, and which failed in Congress because of FEMA's strong support by State and local governments.

With John Lyons' strong interest in NEHRP, NIST endeavored to gain the lead role in support of the development of seismic safety standards and practices, which had been intended for NBS in the NEHRP authorizing legislation, but had been assumed by FEMA when NBS declined to request funding for the role. FEMA wished to keep its role in support of development of building standards and practices because its successes were much appreciated in the private and public sectors and within FEMA. Moreover, the seismic standards and practices community did not support transfer of this role to NIST because it had good working relations with FEMA, was grateful to FEMA for its sustained support over ten years, and had no reason to believe that NIST would provide better support or management. The outcome was that FEMA maintained its role in building standards and practices with technical support from NIST and others, and that NIST assumed responsibility for development, with the community, of seismic safety standards and practices for lifelines (public works and utilities). This and the special funding for investigations of the Loma Prieta earthquake gave CBT hope for a strengthened role in NEHRP. However, over the next several years, NIST was unable to obtain

directly appropriated funding for development of seismic safety standards and practices for lifelines and asked that FEMA assume this role, too.

In cooperation with ENR magazine and the National Institute of Building Sciences on February 27, 1990, CBT co-sponsored the "Roundtable on International Harmonization of Construction Standards and Practices - Assets or Liabilities for Competitiveness" to define private and public sector activities needed for competitiveness of the industries of construction. It was the basis for a feature article "Standards for a Global Market" in the April 19, 1990 *ENR*. CBT also organized and chaired at the Structures Congress of the ASCE a plenary session and a technical session "Prospects for International Engineering Practice." Topics included: Structural Engineering in the European Community, International Harmonization of Standards, Evolution of the U.S. building regulatory system, and International Recognition of Professional Engineering Credentials. CBT also participated in the Japanese Technology Evaluation Center's study of Construction Technologies in Japan which assessed the relative effectiveness of Japanese and U.S. construction research and technology transfer [10].

Edward Garboczi and Dale Bentz published Analytical and Numerical Models of Transport in Porous

Cementitious Materials which represent rate controlling processes including diffusion, convection, reaction and sorption involved in corrosion of reinforcement, sulfate attack, acid attack and leaching.

William Thomas and Douglas Burch completed experiments to determine for important building materials the moisture transfer properties that are critical to build up of moisture in and consequent degradation of building envelopes. This became the basis for the MOIST computer program - a practical means for assessing the vulnerability of building envelope designs to moisture.

James Hill was elected to the ASHRAE Board of Directors. Lorraine Freeman retired after serving as the CBT director's secretary since 1977. Gail Crum succeeded to the position and took charge rapidly and effectively based on her experience as James Wright's secretary in the Building Research Division, CBT, the Institute for Applied Technology, and the National Engineering Laboratory.

References

1. Louis E. Alfeld, *Research for Building Construction Productivity - Report on the June 2, 1981 Conference*, NBS-GCR-81-331, National Bureau of Standards, 1981.
2. *Semiannual Report to the Congress*, April 1, 1983-September 30, 1983, Office of the Inspector General, Department of Commerce, 1983.
3. *National Bureau of Standards Authorization*, Senate Report No. 98-49, Senate Committee on Commerce, Science and Transportation, March 21, 1983.
4. *Authorizing Appropriations to the National Bureau of Standards for Fiscal Year 1984*, House of Representatives Report 98-95, House Committee on Science and Technology, May 9, 1983.
5. *National Bureau of Standards Authorization*, Senate Report No. 98-423, Senate Committee on Commerce, Science and Transportation, 1984.
6. J. M. Evans, editor, *Measurement Technology for Automation in Construction and Large Scale Assembly*, NBSIR 85-3310, National Bureau of Standards, 1985.
7. "An Evaluative Report on the Center for Building Technology," *An Evaluative Report on the National Engineering Laboratory*, National Academy Press, p56, 1984.
8. *Background Information Related to the Proposed Spin-Off of Selected Programs of the National Bureau of Standards*, Congressional Research Service, Library of Congress, February 28, 1986.
9. Richard N. Wright, *Technology for Competitiveness of the U.S. Construction Industry*, NISTIR 89-4099, National Institute of Standards and Technology, 1989.
10. Richard L. Tucker, John W. Fisher, Daniel W. Halpin, R. Nielsen, Boyd C. Paulson, G.H. Watson, and Richard N. Wright, *Construction Technologies in Japan*, Japanese Technology Evaluation Center, Loyola College in Maryland, June 1991.

